Practitioner's Docket No.: 081468-0308135 **PATENT**
Client Reference No.: P-1513.010-US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Confirmation No: 1764

DE BOKX et al.

Application No.: 10/776,641 Group No.: 2851

Filed: February 12, 2004 Examiner:

For: LITHOGRAPHIC APPARATUS COMPRISING A GAS FLUSHING SYSTEM

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

SUBMISSION OF PRIORITY DOCUMENT

Attached please find the certified copy of the foreign application from which priority is claimed for this case:

Country	Application Number	Filing Date
EUROPE	03075416.2	February 12, 2003

Date: May 28, 2004

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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. **Patent application No.** **Demande de brevet n°**

03075416.2

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

Anmeldung Nr:
Application no.: 03075416.2
Demande no:

Anmeldetag:
Date of filing: 12/02/03
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Lithographic apparatus comprising a gas flushing system

In Anspruch genommene Prioriät(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

G03F7/20

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LU MC NL
PT SE SI SK TR LI

Lithographic apparatus comprising a gas flushing system

The present invention relates to a lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate and moving said substrate with a controlled scan velocity;
- a projection system for projecting the patterned beam onto a target portion of the substrate; and
- a gas flushing system.

To reduce the size of features that can be imaged in lithographic projection apparatus, it is desirable to reduce the wavelength of the illumination wavelength. To such end, it has been proposed to use wavelengths of less than about 200 nm, for example 157 nm or 126 nm. However, such wavelengths are strongly absorbed by normal atmospheric air leading to unacceptable loss of intensity as the beam traverses the apparatus. To enclose the entire apparatus and operate in vacuum would introduce unacceptable delays in wafer and reticle exchange whereas to flush the entire apparatus with a gas which does not absorb the illumination wavelength, such as ultra-pure nitrogen (N_2), would result in excessive operating costs due to the consumption of the gas in an imperfectly closed machine.

EP 1098226 describes a system wherein laminar flows are provided by a flushing system comprising a supply and a vacuum pump, and wherein the laminar flows are parallel to e.g. a thin sheet and the mask in the mask stage, or parallel to a last lens and the substrate in the wafer stage. In EP 1098226, the last element in the wafer stage of the projection system PL comprises a kind of "purge hood" on the last lens of the projection system PL, creating a volume between the lens system and the substrate, with walls having an inlet for the flushing gas and an outlet. A disadvantage here is that the flow has to be rather fast in order to prevent the introduction of air/gas outside of the "hood". Another disadvantage might be that at the outlet, also gas outside of the

"hood" is drawn. A further disadvantage might be that the gas introduced inside the hood, leaks to the outside and changes the gas composition outside thc hood. Sensors e.g. for determining the position or height of the wafer, etc, for example based on transmission or index of refraction of the gas, might in this way be disturbed, which leads to less reproducible results.

Next to that, photo-resist polymers are known to take up rather large amounts of water (several vol. %) from ambient air, and this water absorbs part of the incident light, especially light with short wavelengths like 157 or 126 nm. The amount of water remaining during illumination might well lead to a much larger transmission loss than that caused by water in the vapour phase. The total amounts of water absorbed by photo-resist polymers at equilibrium with a 50 % RH (relative humidity) gas atmosphere at 22 °C are exemplary be found between about 1.0 vol. % and 2.5 vol. %. EP 1098226 does not disclose how to dry a resist on the wafer and remove water before the PL beam reaches the resist on the wafer or suggests that this is necessary; the laminar flow may only remove water that is present in de gas phase.

Hence, it is an objcct of the present invention to provide a system that reduces absorption of the projection beam light by water, e.g. on the resist. Another object of the invention is to remove part of the water from the resist before the projection beam reaches the surface of the resist on the substrate, and so increase the transmission of the resist.

According to the present invention, there is provided a lithographic projection apparatus according to the opening paragraph, characterised in that said gas flushing system and said substrate define an intermediate space for a radial gas flow between said gas flushing system and said substrate, said gas flushing system also comprising outlets for generating said radial gas flow, and said gas flushing system, in use, is arranged to generate said radial gas flow such that said radial gas flow has a radial velocity directed outwards in said space with a magnitude larger than zero at every location in said spacc.

The radial gas flow dries or removes part of the water absorbed on and present in the resist, before the projection beam reaches the resist. This advantageously reduces absorption of the projection beam light by water. In this way the transmission loss is minimised, and also differences in transmission are minimised. The atmosphere between the last lens of the projection system and the substrate, and between the gas flushing system and substrate, may now be better controlled. Preferably, the radial gas flow has a velocity equal or higher than the scan speed.

In one embodiment, the gas flushing system further comprises outlets and inlets for generating a substantially laminar gas flow across at least part of said projection beam between a last lens of the projection system and said substrate. In this way, when using such a lithographic apparatus, absorption of the projection beam is minimised while avoiding detrimental effects on the throughput and maintenance overhead of the apparatus as well as reducing the use of expensive consumables. The laminar flow across the last lens of the projection system also decreases the possibility of deposition of organic compounds on the surface of the last lens, e.g. from the resist.

The laminar gas flow generated between the outlets and inlets across at least part of the projection beam between a last lens of the projection system and substrate, preferably comprises a flushing gas that is substantially non-absorbent of said radiation of said projection system, e.g. one or more gases selected from the group comprising of (ultra pure) N_2, He, Ar, Kr, and Ne. The gas which is used for the radial gas flow, which is generated in the volume between the substrate and the gas flushing system may comprises a gas with a composition different from said gas of the laminar gas flow, because the requirements are different for these gases. Preferably, the radial gas flow comprises a gas that has a water contamination of less than 1 ppm, more preferably less than 0.01 ppm, and even more preferably less than about 0.001 ppm.

According a further embodiment of the invention, the gas flushing system further comprises extra exhaust inlets which are located to the outside, with respect to the outlets of said gas flushing system which provide the radial gas flow, and which are arranged to exhaust part or a substantial part of the gas radial gas flow, which is directed outwards in said space. This also leads to a better-controlled atmosphere

outside of the region between the last lens of the projection system and the substrate and thus to better controlled transmissions and indices of refraction. This is advantageous, since e.g. sensors that determine the height of the substrate or the position can be very sensible to slight differences in transmission and/or indices of refraction.

In another embodiment according to the invention, the last lens of the projection system may be comprised in a lower lens element formed of a material substantially transparent to the radiation, and wherein a cover member is substantially planar and is provided substantially parallel to the direction of said laminar flow. Such a component can be provided to cover a non-planar surface of a component, e.g. the last lens, of the lithographic apparatus in or adjacent to said part of said beam path.

According to a further aspect of the invention, there is provided a method of manufacturing a device using a lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate and moving said substrate with a controlled scan velocity;
- a projection system for projecting the patterned beam onto a target portion of the substrate; and
- a gas flushing system, characterised by providing a radial gas flow in an intermediate space between said gas flushing system and said substrate such that said radial gas flow has a radial velocity directed outwards in said space with a magnitude larger than zero at every location in said space.

Hence, this invention especially provides a method and apparatus to reduce water on and in the resist, before the resist is exposed to the radiation, and also a method to reduce the transmission losses as a result of water present in and on the resist.

In a further aspect of the invention, there is provided a method wherein part of the radial gas flow, which is directed outwards, is exhausted, by exhaust inlets, located to

the outside, with respect to the outlets of the gas flossing system of the lithographic projection apparatus.

In another embodiment, the lithographic apparatus used in this method further comprises outlets and inlets for generating a substantially laminar gas flow across at least part of said projection beam between a last lens of the projection system and said substrate.

According to another aspect of the invention, there is provided a device which is manufactured according to the method of the invention or with the apparatus according to the invention.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

In the present document, the terms “radiation” and “beam” are used to encompass all types of electromagnetic radiation, including ultraviolet (UV) radiation (e.g. with a wavelength of 365, 248, 193, 157 or 126 nm or, when applicable, even shorter wavelengths), but especially radiation which has a wavelength less than 200 nm, more preferably about 157 +/- 5 nm or about 126 +/- 5 nm. With "a laminar gas flow" is meant a gas flow that is substantially laminar.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

- Figure 1 depicts a lithographic projection apparatus according to an embodiment of the invention;

- Figure 2 is an enlarged view of the wafer stage of the embodiment of Figure 1 with a gas flushing system according to the state of the art;

- Figure 3 is a schematic drawing of the gas flushing system of one embodiment of the invention;

- Figure 4 is a schematic drawing of another embodiment of the gas flushing system of the invention.

The term "patterning means" as here employed should be broadly interpreted as referring to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate; the term "light valve" can also be used in this context. Generally, the said pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device (see below). Examples of such patterning means include:

- A mask. The concept of a mask is well known in lithography, and it includes mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. Placement of such a mask in the radiation beam causes selective transmission (in the case of a transmissive mask) or reflection (in the case of a reflective mask) of the radiation impinging on the mask, according to the pattern on the mask. In the case of a mask, the support structure will generally be a mask table, which ensures that the mask can be held at a desired position in the incoming radiation beam, and that it can be moved relative to the beam if so desired;

- A programmable mirror array. One example of such a device is a matrix-addressable surface having a viscoelastic control layer and a reflective surface. The basic principle behind such an apparatus is that (for example) addressed areas of the reflective surface reflect incident light as diffracted light, whereas unaddressed areas reflect incident light as undiffracted light. Using an appropriate filter, the said undiffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind; in this manner, the beam becomes patterned according to the addressing pattern of the matrix-addressable surface. An alternative embodiment of a programmable mirror array employs a matrix arrangement of tiny mirrors, each of which can be individually tilted

about an axis by applying a suitable localised electric field, or by employing piezoelectric actuation means. Once again, the mirrors are matrix-addressable, such that addressed mirrors will reflect an incoming radiation beam in a different direction to unaddressed mirrors; in this manner, the reflected beam is patterned according to the addressing pattern of the matrix-addressable mirrors. The required matrix addressing can be performed using suitable electronic means. In both of the situations described hereabove, the patterning means can comprise one or more programmable mirror arrays. More information on mirror arrays as here referred to can be gleaned, for example, from United States Patents US 5,296,891 and US 5,523,193, and PCT patent applications WO 98/38597 and WO 98/33096, which are incorporated herein by reference. In the case of a programmable mirror array, the said support structure may be embodied as a frame or table, for example, which may be fixed or movable as required; and

- A programmable LCD array. An example of such a construction is given in United States Patent US 5,229,872, which is incorporated herein by reference. As above, the support structure in this case may be embodied as a frame or table, for example, which may be fixed or movable as required.

For purposes of simplicity, the rest of this text may, at certain locations, specifically direct itself to examples involving a mask and mask table; however, the general principles discussed in such instances should be seen in the broader context of the patterning means as hereabove set forth.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the patterning means may generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (e.g. comprising one or more dies) on a substrate (silicon wafer) that has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions that are successively irradiated via the projection system, one at a time. In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion in

one go; such an apparatus is commonly referred to as a wafer stepper or step-and-repeat apparatus. In an alternative apparatus - commonly referred to as a step-and-scan apparatus - each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned, for example, from US 6,046,792, incorporated herein by reference.

In a manufacturing process using a lithographic projection apparatus, a pattern (e.g. in a mask) is imaged onto a substrate that is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4, incorporated herein by reference.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric

systems, for example. The radiation system may also include components operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens". Further, the lithographic apparatus may be of a type having two or more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in US 5,969,441 and WO 98/40791, both incorporated herein by reference.

The term gas composition herein refers to pure gases or gas compositions. The term lower lens element herein refers to a last lens of the projection system before the projection beam reaches the substrate, which is usually mounted on a lens mount, e.g. of steel.

Embodiment 1

Figure 1 schematically depicts a lithographic projection apparatus 1 according to a particular embodiment of the invention. The apparatus comprises:

- a radiation system LA (comprises a radiation source), a beam expander Ex, and an illumination system IL, for supplying a projection beam PB of radiation (e.g. 157 nm radiation);
- a first object table (mask table) MT provided with a mask holder for holding a mask MA (e.g. a reticle), and connected to first positioning means PM for accurately positioning the mask with respect to item PL;
- a second object table (substrate table) WT provided with a substrate holder for holding a substrate W (e.g. a resist-coated silicon wafer), and connected to second positioning means PW for accurately positioning the substrate with respect to item PL; and
- a projection system ("lens") PL (e.g. refractive, catadioptric or reflective optics) for imaging an irradiated portion of the mask MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.

As here depicted, the apparatus is of a reflective type (i.e. has a reflective mask). However, in general, it may also be of a transmissive type, for example (with a transmissive mask). Alternatively, the apparatus may employ another kind of patterning means, such as a programmable mirror array of a type as referred to above.

The source LA (e.g. a 157 or a 126 nm laser source) produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after having traversed conditioning means, such as a beam expander Ex, for example. The illuminator IL may comprise adjusting means AM for setting the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator IN and a condenser CO. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its cross-section.

It should be noted with regard to figure 1 that the source LA may be within the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors); this latter scenario is often the case when the source LA is a laser. The current invention and claims encompass both of these scenarios.

The beam PB subsequently intercepts the mask MA, which is held on a mask table MT. Having traversed the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning means PW (and interferometric measuring means IF), the substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the beam PB. Similarly, the first positioning means PM can be used to accurately position the mask MA with respect to the path of the beam PB, e.g. after mechanical retrieval of the mask MA from a mask library, or during a scan. In general, movement of the object tables MT, WT will be realised with the aid of a long-stroke module (coarse positioning) and a short-stroke module (fine positioning), which are not

explicitly depicted in figure 1. However, in the case of a wafer stepper (as opposed to a step-and-scan apparatus) the mask table MT may just be connected to a short stroke actuator, or may be fixed. Mask MA and substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2.

The depicted apparatus can be used in two different modes:

1. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (i.e. a single "flash") onto a target portion C. The substrate table WT is then shifted in the x and/or y directions so that a different target portion C can be irradiated by the beam PB; and

2. In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g. the y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed V = Mv, in which M is the magnification of the lens PL (typically, M = 1/4 or 1/5). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

Figure 2 shows the wafer stage of the lithographic apparatus of Figure 1, comprising a flushing system 200 for generating a flow across part of the projection beam according to the state of the art (e.g. EP 1098226). In the wafer stage there is only a single space to be flushed between a last (lens) element of the projection lens system PL and wafer or substrate W. To avoid having to provide a flushing gas path covering the entire range of movement of the wafer stage, the flushing system 200 comprises flushing gas supply outlets 17 and evacuation inlets 18, which are mounted on a last (lens) element of the projection lens system PL, at either side of the final element. They can also be positioned next to or around the final lens element. By providing outlets 17 and evacuation inlets 18, a laminar or substantially laminar gas flow can be provided and maintained.

Outlets 17 and inlets 18 are respectively connected to a flushing gas supply 11 and a reservoir 12 via flow regulator 117 and vacuum pump 127, respectively. The outlets 17

in particular, but also the inlets 18, may be provided with vanes to guide the flow of flushing gas. Outlets 17 and inlets 18 can be interpreted as the above-mentioned "hood", or also called "purge hood", forming together with the lens and the substrate W a certain volume.

If not already flat, the final element of the projection lens system PL may be covered with a thin sheet, see below.

The flow regulator 117 mentioned above may comprise static or controllable pressure or flow reducers and/or blowers as required to provide the necessary gas flow rates for the particular embodiment and the available gas supply. This also applies for other flow regulators mentioned herein (see below, 137). Vacuum pump 127, or other vacuum pumps mentioned below, may also comprise other means to exhaust part of the gas(ses).

In figure 3, a schematic drawing of the gas flushing system of one embodiment of the invention is shown. Like figure 2, it shows the wafer stage of the lithographic apparatus, comprising a flushing system 200 with flushing gas supply outlets 17 and evacuation inlets 18, which are mounted on a last (lens) element 21 of the projection lens system PL, on either side of the last element.

The spaces traversed by the projection beam PB are flushed with a laminar flow of (ultra-pure) nitrogen (N_2), or other gas (e.g. Helium, Argon or Xenon) transparent to the illumination radiation used. To ensure laminar flow between 17 and 18 and minimise turbulence, all parts may be smoothed, as far as possible. The effective Reynolds number of the system is thereby reduced. Due to the minimisation of turbulence vortices, contamination of the flushing gas is minimised and the gas may be recovered and re-used (e.g. by unit 12). Re-use of the gas may be in the same area from which it was recovered or may be elsewhere, e.g. in a cascade fashion. In such an arrangement, fresh flushing gas is supplied to the most critical area(s) and may then re-used in successively less critical areas. The flushing gas may of course be cleaned or scrubbed before re-use and mixed with fresh gas as desired to control contamination levels.

EP 1098226, which is herein incorporated by reference, describes that ultra-pure nitrogen (N_2), as flushing gas, has an extinction coefficient, k, at 1 standard atmosphere of less than about 0.0001 per cm traversed, as compared to air at 1 standard atmosphere for which k is approximately 46 per cm traversed. The actual gas pressure in the beam path may be above atmospheric pressure. Flushing nitrogen, or another relevant flushing gas, may be provided at high purity, i.e. with an air and/or water contamination of less than 1 ppm, preferably less than 0.1 ppm, more preferably less than 0.01 ppm, and even more preferably less than 0.001 ppm. Preferably, the contamination with air is less than 5 ppm, more preferably less than 1 ppm, and even more preferably less than 0.1 ppm.

To ensure laminar flow, the last lens element 21 may comprise e.g. a sheet or pellicle of a material substantially transmissive to the employed radiation, such as CaF_2, MgF_2, BaF_2, fused SiO_2, or any other material that can form a sheet or pellicle which has a high transmission for the wavelength of the radiation used in the lithographic apparatus. Polymer pellicles are preferably avoided to avoid diffusion across them. In some embodiments of the invention, the pellicle may be omitted altogether, in which case the flushing gas supply is simplified. The flushing gas supply system 200, which is mounted on, or around, last lens mount 21, is also called "purge hood".

In this embodiment, as schematically drawn here, the purge hood has a lower surface that is substantially parallel to the wafer, however, this surface can also be bended and/or have an angle with respect to the wafer. Usually however, the gas supply system of this embodiment will have a lower surface which is substantially parallel to the wafer.

Gas flushing system 200 further comprises, according to this embodiment of the invention, extra outlets 202, which are connected to the flushing gas supply 11 via a flow regulator 137. For the sake of understanding, outlets 202 and flow regulators 137 are drawn on both sides of the projection beam, but it should be taken into account that the drawing to this respect is symmetric, and the outlets 202 are all around the beam and only one flow regulator 137 may be necessary. Nevertheless, this embodiment also comprises the option that the outlets 202 belong to different compartments, which each

have there own flow regulator 137. In this way, an even better controlled externally directed radial gas flow 203 can be generated.

Between the purge hood and the wafer, gas flow 203 created by the gas coming from the outlets 202 travels along a certain length 201, which is defined as the length between the outlet 202 at the projection beam side and the outer side of the gas flushing system 200 (see also figure 3); in other words it is the width of the space between the purge hood and substrate W.

The speed of the externally directed gas flow 203 can be regulated by flow regulator 137, but is also a function of the speed and pressure of the gas flow between 17 and 18, which can be regulated by flow regulators 117 and vacuum pump 127. The laminar and radial gas flows are adjusted in such a way that at the used scan velocity, the velocity of the radial gas flow 203, at every location in the space between the gas flushing system and the substrate is higher than zero and directed outwards. The radial gas flow velocity is the vectorial sum of gas flow speed created at the outlets 202 and the scan speed. When the requirement of radial gas flow with a velocity higher than zero and directed outwards is fulfilled, dry gas is provided above the resist, reducing the amount of water on and in the resist. This leads to the above-mentioned advantages like reduction of transmission loss. Preferably, the radial gas flow has a velocity substantial higher than zero at every location in space, e.g. equal or preferably higher than the scan speed, preferably at least in the scanning direction.

Gas from the surroundings will nowhere substantially enter the area under the purge hood. Of course, there will always be some diffusion and turbulence, causing some gas from the surroundings entering the volume under the purge hood, but when the gas speed is high enough, this gas will substantially not enter the volume of the projection beam PB between 17, 18 and the substrate W.

The amount of water in the resist will depend on the resist layer thickness. Assuming 157 nm lithography and a resist layer thickness of approximately 200 nm or less, it surprisingly appears that drying the resist by the radial gas flow 203 with a purge gas N_2, He, Xe etc. leads to a reduction of transmission loss of about 10% to about 1% in a

period of less than about 0.01 s. The transmission loss left (about 1%) is due to remnant water, which is more strongly bound in the resist. Preferably, the gas that is supplied, has a water contamination of less than 1 ppm, preferably less than 0.01 ppm, and more preferably less than about 0.001 ppm.

This means that length 201, should be about 0.01s times the scan velocity. Taking for example a scan velocity of about 0.3 m/s, this means that already a length 201 of about 3 mm would be enough. Preferably, the length 201 is at least about 5 mm, more preferably at least about 10 mm, and most preferably at lcast about 20 mm. Of course this calculated length 201(i.e. substantially the width of the space between the purge hood and substrate W (i.e. resist on substrate W)), depends upon the water amount in the resist, which on its turn is a function of the resist thickness, and also depends on the scan speed. The values given here are especially applicable for resists known in the art for these applications, with a resist thickness of about 200 nm. The person skilled in the art will choose the wavelength, resist, resist thickness, scan speed, in such a way that optimal results will be obtained. The lengths given here, especially apply for a lithographic apparatus using radiation of 157 nm, and above mentioned resist thickness.

By using such a length 201, i.e. such a drying length, a substantial part of water, mainly loosely bound water, present in and on the resist, is removed and transported to the regions outside of the purge hood (gas flushing system 200). Hence, transmission differences are minimised. In a lithographic apparatus without the gas flushing system of the invention, transmission losses were about 10%. Now, the transmission losses, when using the apparatus of the invention, is about 1% or less, preferably less than 0.1%. In this way, more reproducible results, i.e. better IC's, are obtained, and e.g. sensors to determine the substrate height are hindered less by differences in transmission or indices of refraction.

In figure 3, outlets 202 are connected to flushing gas supply 11. However, this embodiment also comprises the possibility wherein the gas supply 11 contains different gas supplies. In this way, radial gas flow 203 from outlets 202 may comprise a gas with a composition different from said gas of the laminar gas flow. Since the requirements for the gas flow 203 (e.g. gas able to dry resist), and the laminar flow between 17 and

18 (at least transparent for the projection beam PB), may be different, the composition of these gasses can be different. Then, different gas supplies 11 are necessary.

Next to the substrate W, elevations 210 may be present to make the surface under the projection beam and "purge hood" (more) flat. Preferably, these elevations 210 have the same height as substrate W, with a possible difference in height of preferably less than 0.5 mm, more preferably less than 0.1 mm, even more preferably 0.01 mm or less. The same applies for the splits or fissures between especially the substrate W and the elevation(s) 210. The width of this split is preferably less than 0.5 mm, more preferably less than 0.1 mm, even more preferably 0.01 mm or less. The elevation(s) 210 can be again one elevation or a number of elevations, e.g. all around substrate W. It can also comprise sensors, e.g. sensors to determine the speed, height etc. In this way, substrate table WT can have a square or rectangular shape with a saving for the substrate, and wherein the substrate is surrounded by an elevation 210, or a number of elevations 210. In these elevations 210, sensors can be present, having the same height as the elevation (these sensor might be covered if necessary to obtain a flat surface with substantially the same height as elevation 210). By reducing the widths of the slits and the differences in height, a flat surface is obtained, which is beneficial for the radial gas flow 203 and for reducing possible turbulences.

Embodiment 2

Figure 4 depicts a second embodiment according to the invention. This embodiment is substantially the same as the previous embodiment, but now the gas flushing system 200 further comprises exhaust inlets 19, located at the outside of the purge hood, with respect to the outlets 202, of said gas flushing system 200, arranged to exhaust part of the radial gas flow 203. In this way, part, or a substantial part of the radial gas flow 203 is exhausted by exhaust inlets 19.

The exhausts 19 are shown in the schematic drawing as separate exhausts, but they are meant to be a series of exhausts, all around the outlets 202, which are on their turn all around or substantially around the lens or last lens element 21 of the projection system PL. The exhausts 19 are connected to a vacuum pump 147, which again can be a number of vacuum pumps (or means to exhaust). Vacuum pump 147 may be connected

to reservoir 12, and in case different gas compositions are used for the volume where the PB is found and for the volume below the gas flushing system 200, they may be connected to a number of reservoirs 12. The exhausts 19 need not necessarily be connected to the purge hood, i.e. be part of the gas flushing system 200.

Now length 201 is defined as the length (or width) between outlet 202 at the projection beam side and inlet 19. Preferably, the length 201 is at least about 5 mm, more preferably at least about 10 mm, and most preferably at least about 20 mm.

In this way, purge gas, that might have different characteristics, like index of refraction, than the gas or gas mixture outside of the purge hood, does not substantially escape to the outside. Hence, more reproducible results, i.e. better IC's, are obtained, since e.g. sensors to determine the substrate height, speed or position, which are placed outside of the volume between the last lens element and the substrate, are hindered less by differences in transmission or indices of refraction of the gas(ses).

In any of the spaces, aerodynamic features such as small strips or fins may be provided as desired to smooth or guide the flushing gas flow and eliminate or control vortex production.

Further, the gas flushing system of the invention and the related parts like regulators, vacuum pumps, reservoirs etc, may further comprise flow restrictors, blowers, flow control members, e.g. provided in said part of said beam path to direct said laminar flow or reduce turbulence therein, etc. It may also comprise sensors to measure e.g. gas flow velocities or gas compositions, etc.

Whilst specific embodiments of the invention have been described above, it will be appreciated that the invention may be practised otherwise than as described. The description of the embodiments and the figures are not intended to limit the invention. For example, the embodiments and figures comprise a gas flushing system for creating a laminar flow, but according to the invention, such laminar flow is a feature that is preferable, but its presence is not necessary to obtain the advantages of the invention.

Claims

1. A lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam (PB) of radiation;

- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam (PB) according to a desired pattern;

- a substrate table for holding a substrate (W) and moving said substrate (W) with a controlled scan velocity;

- a projection system for projecting the patterned beam onto a target portion of the substrate (W); and

- a gas flushing system (200), characterised in that said gas flushing system (200) and said substrate (W) define an intermediate space for a radial gas flow (203) between said gas flushing system (200) and said substrate (W), said gas flushing system (200) also comprising outlets (202) for generating said radial gas flow (203) and said gas flushing system (200), in use, is arranged to generate said radial gas flow (203) such that said radial gas flow (203) has a radial velocity directed outwards in said space with a magnitude larger than zero at every location in said space.

2. Apparatus according to claim 1, further comprising outlets (17) and inlets (18) for generating a substantially laminar gas flow across at least part of said projection beam (PB) between a last lens of the projection system (PL) and said substrate (W).

3. Apparatus according to claim 1 or 2, defining a length (201), between said outlets (202) at the projection beam side and the outer side of said flushing system (200), parallel with said substrate (W) and underneath of said gas flushing system (200), wherein said length (201) is at least about 5 mm.

4. Apparatus according to one of the preceding claims, wherein said gas flushing system (200) further comprises exhaust inlets (19), located to the outside, with respect to the outlets (202), of said gas flushing system (200), arranged to exhaust part of the gas radial gas flow (203).

5. Apparatus according to claim 4, defining a length (201), between said outlets (202) at the projection beam side and the inlets (19) of said flushing system (200), parallel with said substrate (W) and underneath of said gas flushing system (200), wherein said length (201) is at least about 5 mm.

6. Apparatus according to one of claims 3-5, wherein said length (201) is at least about 10 mm.

7. Apparatus according to one of claims 3-5, wherein said length (201) is at least about 20 mm.

8. Apparatus according to one g claims 2-7, wherein said laminar gas flow generated between outlets (17) and inlets (18) across at least part of said projection beam (PB) between a last lens of the projection system (PL) and said substrate (W), comprises a flushing gas being substantially non-absorbent of said radiation of said projection system.

9. Apparatus according to claim 8, wherein said flushing gas comprises one or more gases selected from the group comprising N_2, He, Ar, Kr, and Ne.

10. Apparatus according to claim 8 or 9, wherein said flushing gas in said part of said beam path has a contamination of air of less than 5 ppm, preferably less than 1 ppm, more preferably less 0.1 ppm.

11. Apparatus according to one of claims 8-10, wherein said flushing gas has an extinction coefficient, k, less than 0.005 per cm, preferably less than 0.001 per cm for said radiation.

12. Apparatus according to one of the preceding claims, wherein said radial gas flow (203) comprises a gas that has a water contamination of less than 1 ppm, preferably less than 0.01 ppm, and more preferably less than about 0.001 ppm.

13. Apparatus according to any one of the preceding claims, further comprising a lower lens element (21) formed of a material substantially transparent to said radiation, a cover member being substantially planar and provided substantially parallel to the direction of said laminar flow to cover a non-planar surface of a component of said lithographic apparatus in or adjacent to said part of said beam path.

14. Apparatus according to claim 13, wherein said material substantially transparent to said radiation is selected from the group comprising: CaF_2, SiO_2, MgF_2 and BaF_2.

15. Apparatus according to any one of the preceding claims, wherein said radiation of said projection beam has a wavelength less than 200 nm, preferably 157 +/- 5 nm or 126 +/- 5 nm.

16. Apparatus according to one of claims 2-15, wherein said radial gas flow (203) from outlets (202) comprises a gas with a composition different from said gas of the laminar gas flow.

17. A method of manufacturing a device using a lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam (PB) of radiation;
- a support structure for supporting patterning means, the patterning means serving to pattern the projection beam (PB) according to a desired pattern;
- a substrate table for holding a substrate (W) and moving said substrate (W) with a controlled scan velocity;
- a projection system for projecting the patterned beam onto a target portion of the substrate (W) ; and
- a gas flushing system (200), characterised by providing a radial gas flow (203) in an intermediate space between said gas flushing system (200) and said substrate (W), such that said radial gas flow (203) has a radial velocity directed outwards in said space with a magnitude larger than zero at every location in said space.

18. Method according to claim 17, wherein the gas flushing system further comprises outlets (17) and inlets (18) for generating a substantially laminar gas flow across at

least part of said projection beam (PB) between a last lens of the projection system (PL) and said substrate (W).

19. Method according to claim 17 or 18, wherein part of said radial gas flow (203) is exhausted, by exhaust inlets (19), located to the outside, with respect to the outlets (202) of said gas flushing system (200) of said lithographic projection apparatus.

20. Method according to one of claim 17-19, or apparatus according to one of claims 1-15, wherein the radial gas flow (203) has a velocity equal or higher than the scan speed.

21. A device manufactured according to the method of one of claims 17-20 or with the apparatus according to one of claims 1-16.

Abstract

The invention is related to a lithographic projection apparatus comprising a gas flushing system wherein this gas flushing system and a substrate define an intermediate space for a radial gas flow between the gas flushing system and the substrate, and wherein the gas flushing system also comprising extra outlets for generating the radial gas flow, and wherein the gas flushing system, in use, is arranged to generate this radial gas flow such that the radial gas flow has a radial velocity directed outwards in said spacc with a magnitude larger than zero at every location in said space.

Fig 1

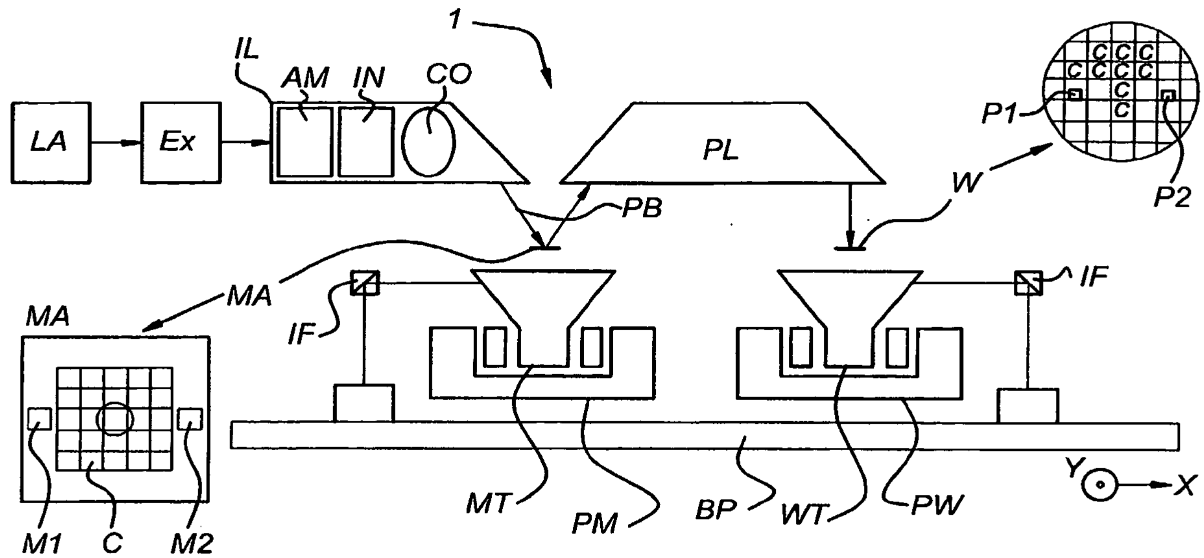
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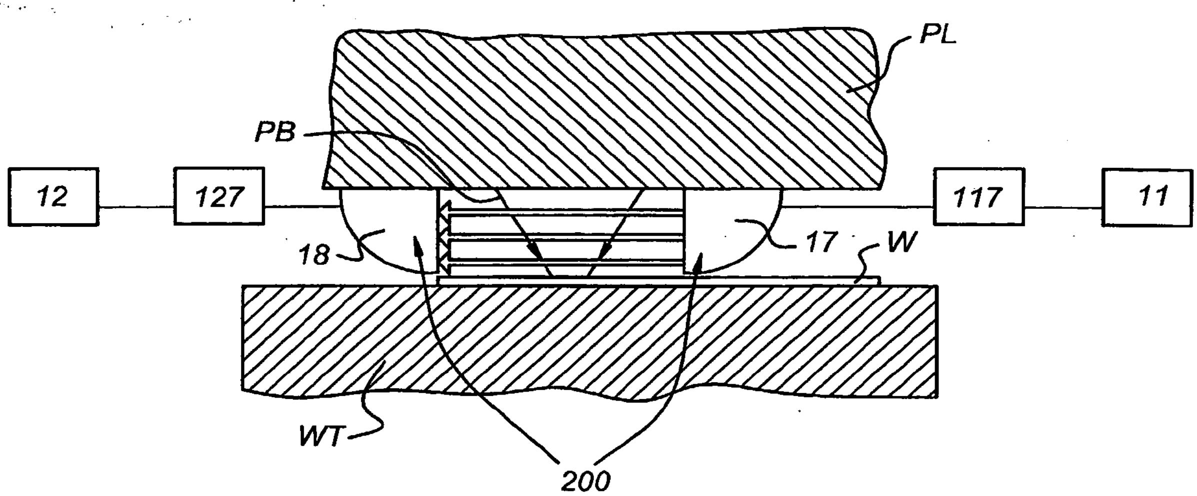
Fig 2


PL
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11
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200

Fig 3

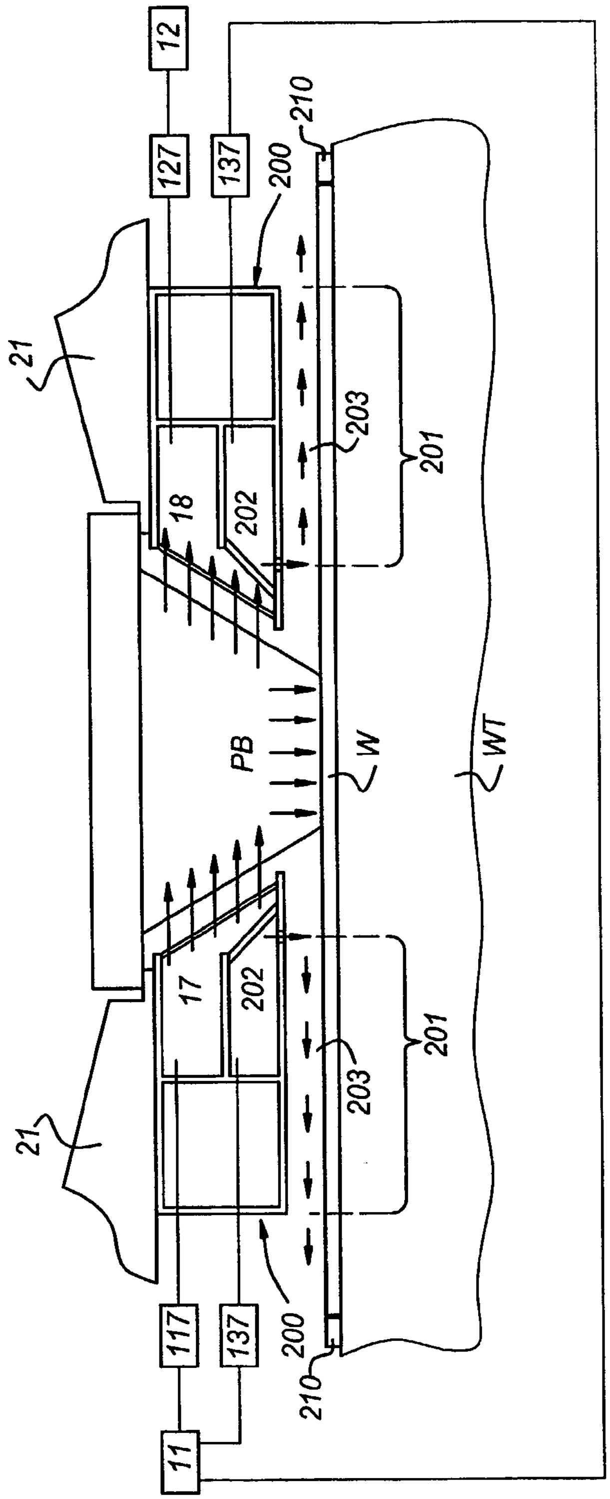
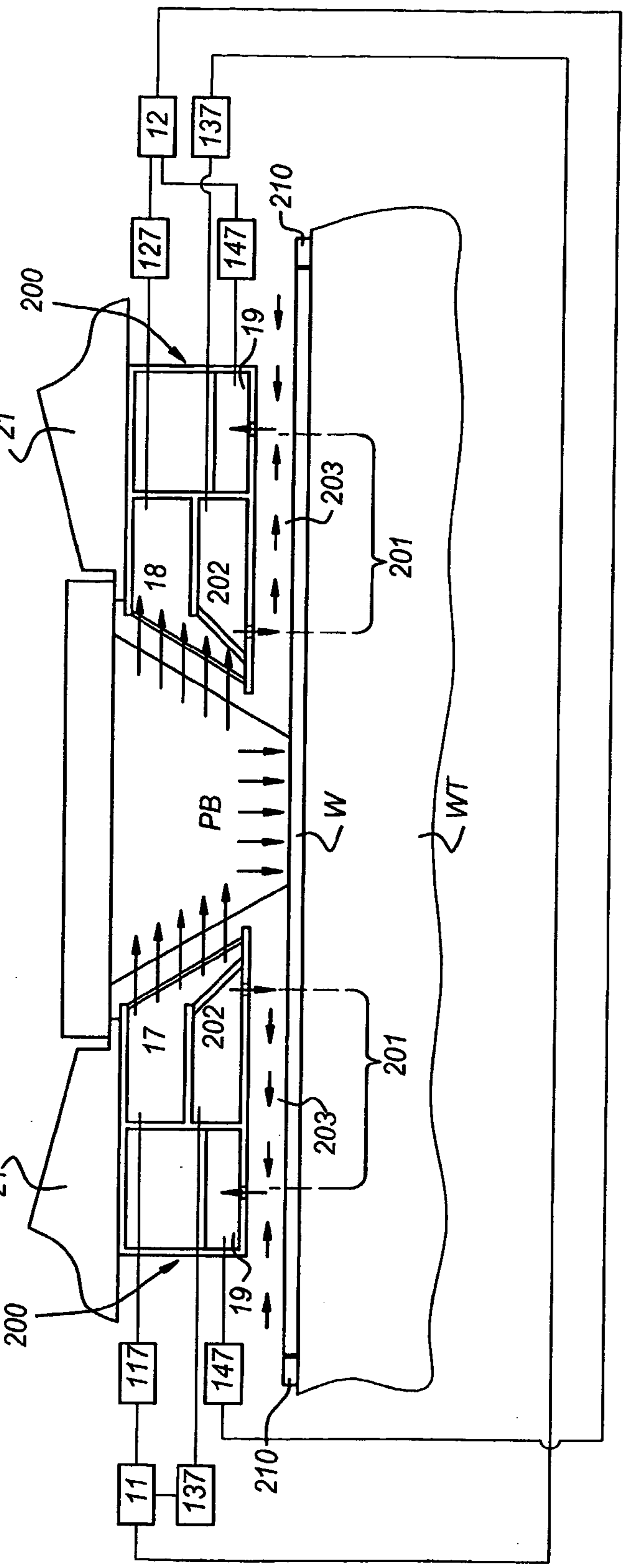


Fig 4



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